Seeing the Forest for the Trees

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Abstract. Climate sensitivity is substantially higher than IPCC's best estimate (3°C for doubled CO_2), a conclusion we reach with greater than 99 percent confidence. We also show that global climate forcing by aerosols became stronger (increasingly negative) during 1970-2005, unlike IPCC's best estimate of aerosol forcing. High confidence in these conclusions is based on a broad analysis approach. IPCC's underestimates of climate sensitivity and aerosol cooling follow from their disproportionate emphasis on global climate modeling, an approach that will not yield timely, reliable, policy advice.

Our two recent papers (Global warming in the pipeline[1] and Global warming has accelerated[2]) [hereafter Paper 1 and Paper 2] were long – due to our research approach and our intent to raise numerous issues. Thus, we summarize the most important conclusions here.

Principal objectives of research in climate change are to evaluate climate sensitivity and the forcings that are driving climate change. Our analysis approach places comparable emphasis on each of three sources of information: (1) paleoclimate data, i.e., the long history of climate change, (2) modern observations of ongoing climate change, and (3) global climate modeling. Full exploitation of all three research tools allows conclusions to be reached with a higher degree of confidence than otherwise would be possible.

We summarize these three analyses, each in a page or at maximum two pages. These summaries are intended for people with some scientific bent. If we do not get such people to appreciate the science, the clique (see below) will continue to obfuscate reality. However, these summaries still make for a long document. Here we skip to the Summary.

4. Summary: seeing the forest for the trees

Climate change depends on climate sensitivity and the strength of the forcing that drives change. Of the main sources of information – paleoclimate, modern observations, and GCMs – the first two are least ambiguous, but all three are consistent with climate sensitivity 4.5°C ± 1°C (2σ, 95% confidence) for doubled CO_2, which excludes IPCC's best estimate of climate sensitivity (3°C for doubled CO_2). IPCC also underestimates the strength of the aerosol climate forcing.

In the real world, climate sensitivity and aerosol forcing are independent, but they are joined at the hip in climate assessments that focus on the ability of GCMs to reproduce observed global warming. It is reasonable that climate modelers use observed global temperature change to help constrain the GCMs. The complication is that there are two major unknowns: climate sensitivity (mainly because the cloud feedback is uncertain) and the climate forcing (because the aerosol forcing is unmeasured), while there is only one hard constraint (the observed global warming rate). As a result, if climate sensitivity turns out to be high, greater aerosol forcing (i.e., greater aerosol cooling) is required for agreement with observed global temperature.

Independent sources of information, from paleoclimate on climate sensitivity and from satellite data on the cloud feedback, show that, in reality, climate sensitivity is high. Thus, aerosol forcing (and the aerosol cooling effect) have also been underestimated by IPCC. In addition, aerosol cooling has weakened since 2005, mainly because of reduced emissions from China and ships.

Those are the principal conclusions of our two papers ("Global warming in the pipeline" and "Global warming has accelerated") that address the fundamental issues of climate sensitivity and the human-made climate forcing. These issues are a large part of the "forest" of climate science.

Within that part of the climate science forest, many uncertainties remain. For example, how does the cloud feedback work? Tselioudis *et al*.[3] suggest that it is mainly from a poleward shifting of climate zones, as opposed to an effect of global warming on cloud microphysics. It is important to understand such issues, as the correct explanation may affect continuing climate change.

Another example: we argue that reduction of ship aerosols has more effect on global temperature than reduction of aerosols from China, even if the mass reduction of Chinese emissions is larger. Ships emissions are more efficient in affecting clouds because they are injected into relatively pristine ocean air at altitudes that have greatest effect on cloud formation. Observed global distributions of albedo and temperature change are consistent with a large role for ship emissions, although alternative explanations for those distributions may be possible. Temporal changes of albedo and temperature also match better with the 2015 and 2020 changes of ship emissions, rather than with the decrease of emissions from China, which began in 2006.

The forest of climate science includes other areas – besides climate sensitivity and climate forcings – that are also important. For example, potential impacts of climate change include shutdown of the overturning ocean circulation and large sea level rise,[4] which may be the most important of all the climate issues. These climate impacts depend on the magnitude of global warming, which is a reason to first consider climate sensitivity and climate forcings.

5. Communication of the climate situation

The Secretary General of the United Nations asserts that the goal of keeping global warming under 1.5°C is still reachable if nations increase their ambitions for future emission reductions. In reality, the 1.5°C goal has long been deader than a doornail. This raises the question: are we, the scientific community, doing an adequate job of informing governments and the public?

In our present communication, we criticize IPCC's science analysis. However, despite the flaws that we note, IPCC is doing what they were asked to do. Their reports contain authoritative information painstakingly written by experts in their fields. The reports are useful references, but governments and the public need more to properly inform their decision-making.

When we presented our most recent paper,[2] responses in the media by other scientists consisted of ad hominem attacks on the first author, e.g., "Hansen exaggerates," "Hansen makes lots of mistakes," "Hansen is not collegial," and comments that our analysis was "too simple" and our conclusions were "outside the mainstream." None of the comments addressed the climate science in our paper, which we have summarized here. Yet these few articles in the media, appearing on the day that our paper came out, were sufficient to shut down public discussion of our paper.

Issues raised in our paper are relevant to understanding the course of climate change. So, how is it that a small (all-male)[5] clique is able to control the climate research conversation? At least they spurred the first author to move back to Columbia University (see End of an Era),[6] where it may be possible to work more with young people, and hopefully communicate more effectively.

We are grateful to the people who continue to support CSAS. This year, our long-time friend, colleague, and senior scientist Makiko Sato retired. Her unique combination of scientific and

artistic abilities is irreplaceable; her dedication as our climate data expert will be sorely missed. The consolation is that we can now support two entry-level positions at Columbia University: one specializing in climate data and one as program coordinator for CSAS, a position that has been vacant for the past several years. Gen Z is coming of age; we hope to find new graduates ready to realize their potential to help shape the future.

6. International Court of Justice

Let's end on a bright, scintillating, note: the recent ruling by the International Court of Justice in the Hague on global climate change, which deserves far more attention than it has received. It is the first time that the ICJ has taken up climate change. In a unanimous decision the Court determined that:

> ". . . customary international law sets forth obligations for States to ensure the protection of the climate system and other parts of the environment from anthropogenic greenhouse gas emissions. These obligations include the following:
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> (a) States have a duty to prevent significant harm to the environment by acting with due diligence and to use all means at their disposal to prevent activities carried out within their jurisdiction or control from causing significant harm to the climate system and other parts of the environment, in accordance with their common but differentiated responsibilities and respective capabilities;
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> (b) States have a duty to co-operate with each other in good faith to prevent significant harm to the climate system and other parts of the environment, which requires sustained and continuous forms of co-operation by States when taking measures to prevent such harm. . . ."

Philippe Sands, legal scholar, author, and leader in getting the case before the Court and arguing the case, was thrilled that the Court's ruling was even stronger than he had hoped. Over time, this ruling surely will be used extensively and affect courts globally, even within the United States, despite the fact that such ICJ decisions are advisory.

My long-time attorney Dan Galpern and I went to the Hague during the trial, even though we knew that I would not be able to deliver testimony before the Court that I had prepared at the request of the government of Mauritius (because that government had since been turned out of office in an election). Instead, I presented my testimony[7] in a press briefing organized with the help of Eelco Rohling, which included discussions by Rohling and his Utrecht University colleagues Appy Sluijs (Prof. of Paleo-oceanography) and Ingrid Robeyns (Prof. of Ethics of Institutions) and by Dan Galpern.

Philippe Sands notes that at least some of the judges read my testimony, it was mentioned during their proceedings, and Sands believes that it affected their ruling. I mention this because CSAS donors have been supporting our legal efforts for many years. The legal approach can be slow and often ends in disappointment, but it is an essential part of actions to preserve climate, and thus we want to emphasize the successes.

Fireflies. Lastly, I note that Lightning bugs are making a comeback this summer. We will miss the displays we saw on our farm in Bucks County, but I will see if there are any in Riverside Park. Longterm, insects[8] will depend on whether insecticides and herbicides are controlled.

[1] Hansen J, Sato M, Simon L *et al*. "Global warming in the pipeline," *Oxford Open Clim. Chan.* **3(1)**, 2023, doi.org/10.1093/oxfclm/kgad008

[2] Hansen JE, Kharecha P, Sato M *et al.* Global warming has accelerated: are the United Nations and the public well-informed? *Environ.: Sci. Pol. Sustain. Devel.* **67(1)**, 6–44, 2025, https://doi.org/10.1080/00139157.2025.2434494

[3] Tselioudis G, Rossow WB, Bender F *et al*., "Oceanic cloud trends during the satellite era and their radiative signatures," *Clim. Dyn.*: doi.org/10.1007/s00382-024-07396-8, 2024

[4] Hansen J, Sato M, Hearty P *et al*., "Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observations that 2C global warming is highly dangerous," *Atmos Chem Phys* **16**, 3761-812, 2016

[5] It reminds us of something that our mothers (and surely many others) said: "if the world were run by women, we wouldn't be in such a mess."

[6] Hansen J. End of an era, CSAS Communication, 22 May 2025

[7] Hansen J. Climate Change at the International Court of Justice, CSAS Communication, 09 December 2024

[8] Hansen J. Sentinel for the Insect World, CSAS Communication, 01 March 2021